Air Force Weather Agency

Fly - Fight - Win

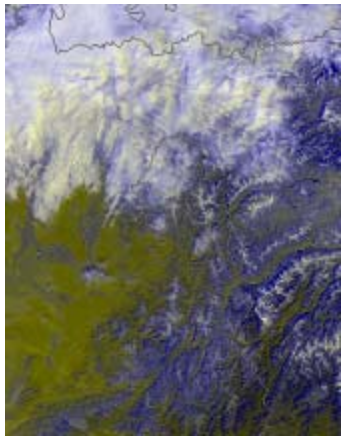
The Land Information System

John Eylander
Environmental Models Branch

U.S. AIR FORCE

AFWA mission:
A Global Team for the Global Fight

Maximizing America's Air, Space, Cyberspace, and Land Power by enabling decision makers to exploit relevant environmental information across the full spectrum of warfare.



AFWA Numerical Weather Prediction System

Mission Support Roles

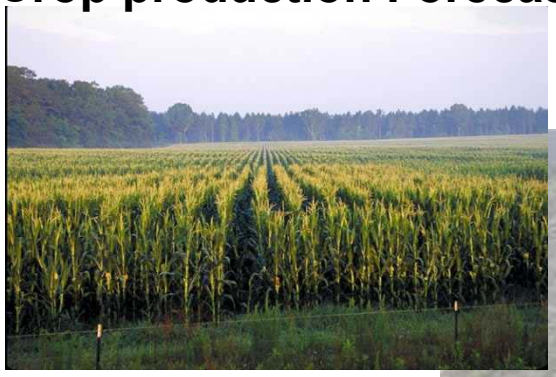
- Global cloud analysis and forecasting mission supports Air Force core mission areas
  - Flight Planning & refueling
  - Targeting
  - ISR
- Global Analysis supports weather prediction modeling
  - Cloud information used for PBL energy balance considerations

AFWA Numerical Weather Prediction System

Mission Support Roles

Time Critical Precision Targeting

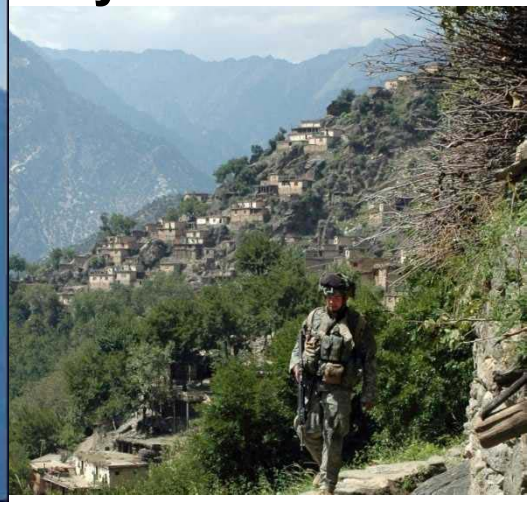
Crop production Forecasting



Precision Air Drop

Mobility decisions

Dust/Dispersion Forecasting



Collaborators

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Most of the LIS related material in this presentation originates from NASA GSFC Hydrological Sciences Branch personnel completed for AFWA funded LIS research and development project reviews.

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LIS Development Team

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Land Information System

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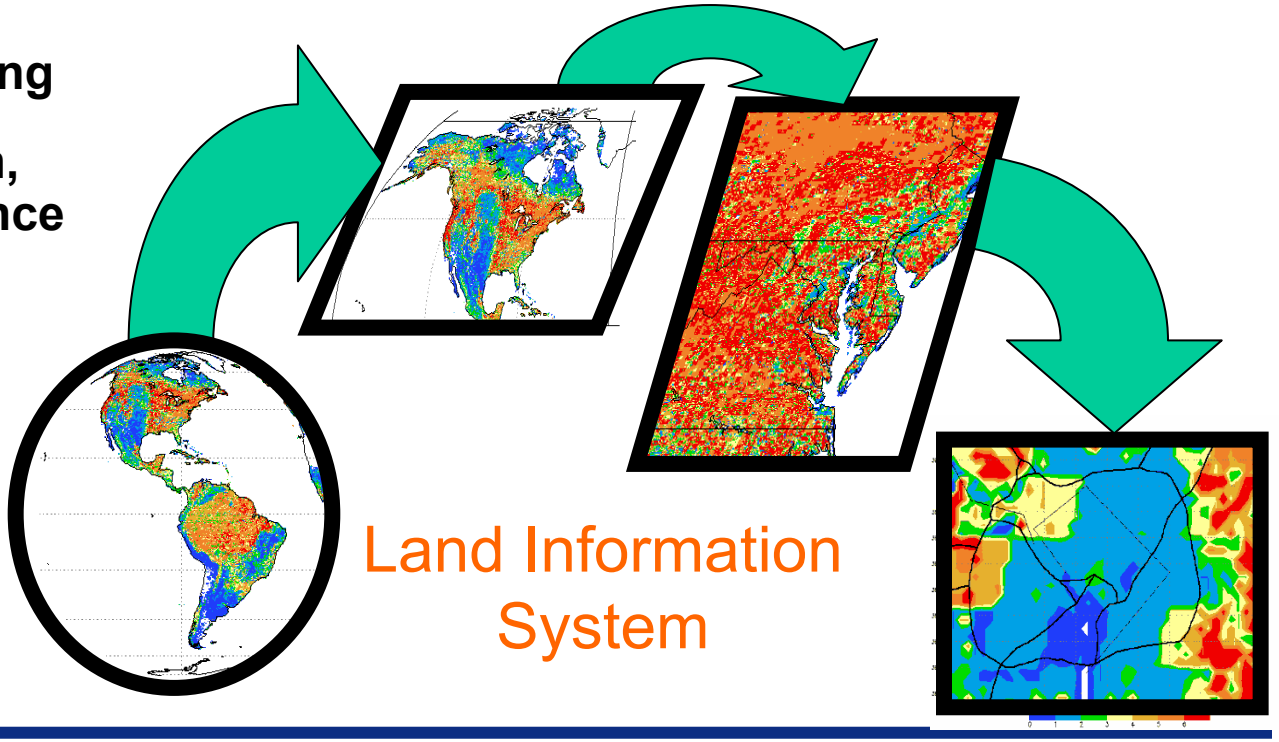
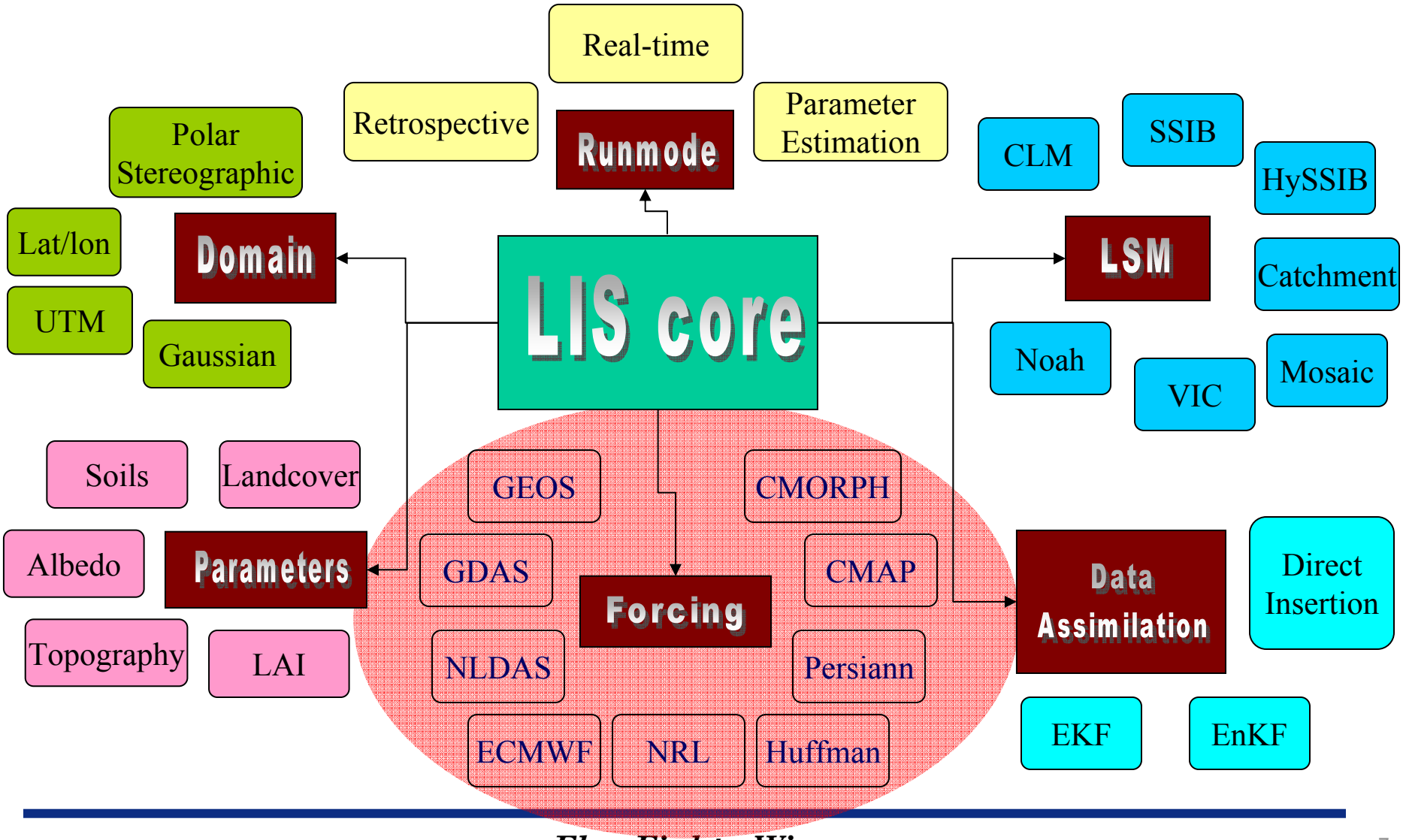
- **NASA developed Land Information System (LIS)**
  - **3 year (FY02 – FY05) NASA ESTO Computational Technologies Project**
- **Goals:**
  - **Realistic Land Surface Modeling**
  - **High resolution, High performance computing**
  - **Efficient data management**
  - **Interoperable & Portable**

Source: http://lis.gsfc.nasa.gov



LIS Design - Extensibility



Benchmarking Project

Completed in 2006

- **Goal 1**: Integrate the capabilities of
  - AFWA Agricultural Meteorology (AGRMET) Model
    - Precipitation, radiation, and surface forcing algorithms
    - Grid processing and GriB output software
  - NASA Land Information System
    - Highly efficient, portable, and modular software engineering
    - Common infrastructure for rapid R&D insertion into operations
- **Goal 2**: Demonstrate capability to generate high resolution regional analyses for AFWA Weather Research & Forecasting (WRF) model initialization

DoD High Performance Computing Center Program (HPCMP) Naval Oceanographic Office (NAVO) Major Shared Resource Center (MSRC) IBM cluster 1600 system (Kraken).

Kraken has 368 nodes with eight 1.7GHz Power4+ processors each. Kraken uses a proprietary network and IBM's High Performance Switch (HPS), also know as Federation, to communicate between nodes. The switch provides ~7-14 microsecond latency with a raw bandwidth of 2 GBps.

Configurable
High Resolution Land States Analyses

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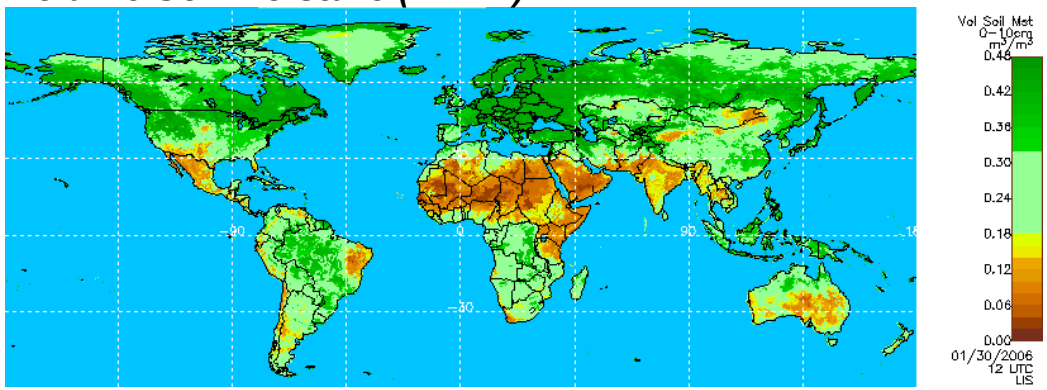
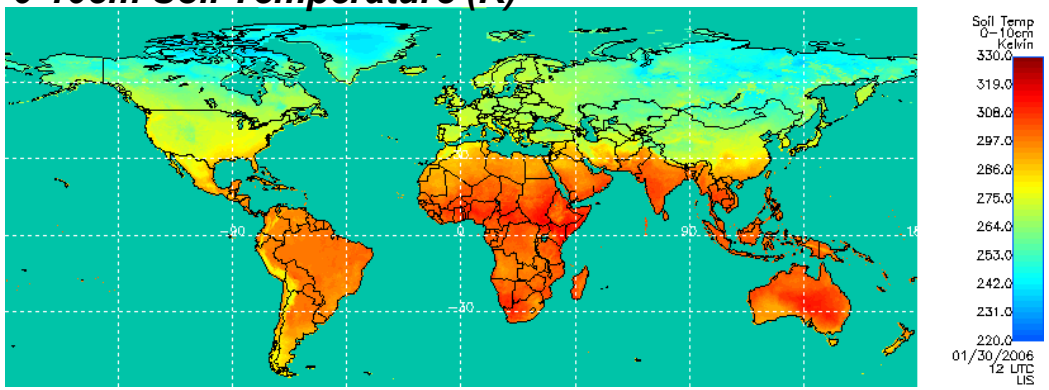
Global

½ degree lat/lon 0-10 cm soil moisture and temperature products

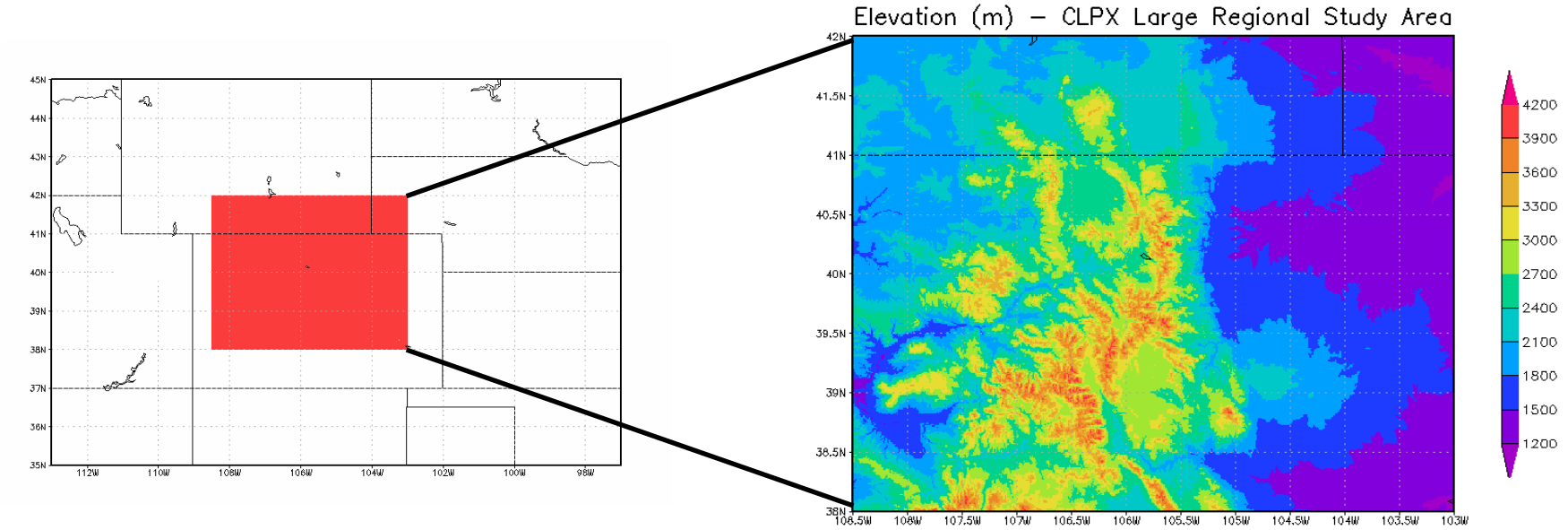
Volume Soil Moisture (m^3/m^3)

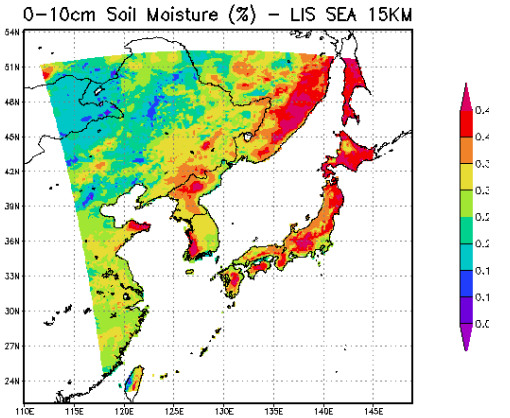


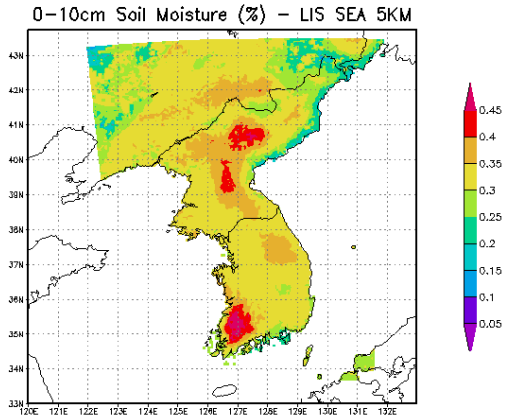
0-10cm Soil Temperature (K)



Configurable
High Resolution Land States Analyses







- **Above: 1km CLPX region study (550 x 400 grid points)**
- **Bottom Grid: Southeast Asia case study**

Current LIS Development

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The New Common Data Assimilation Module*

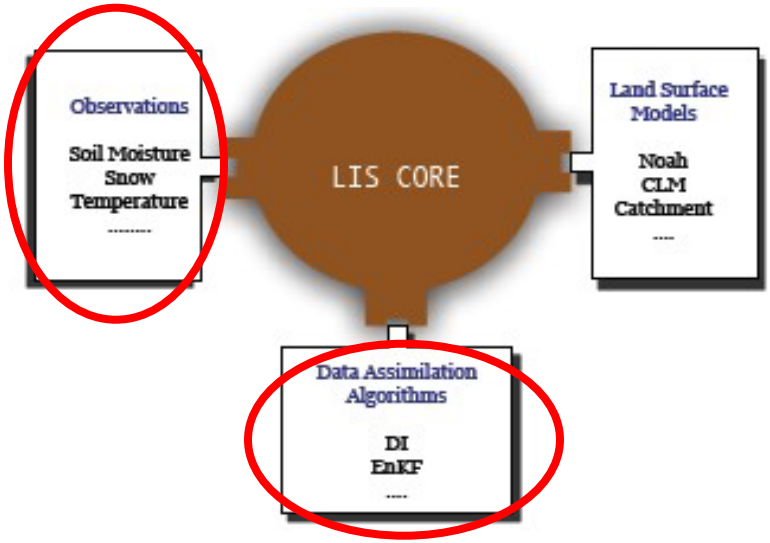
Featuring:

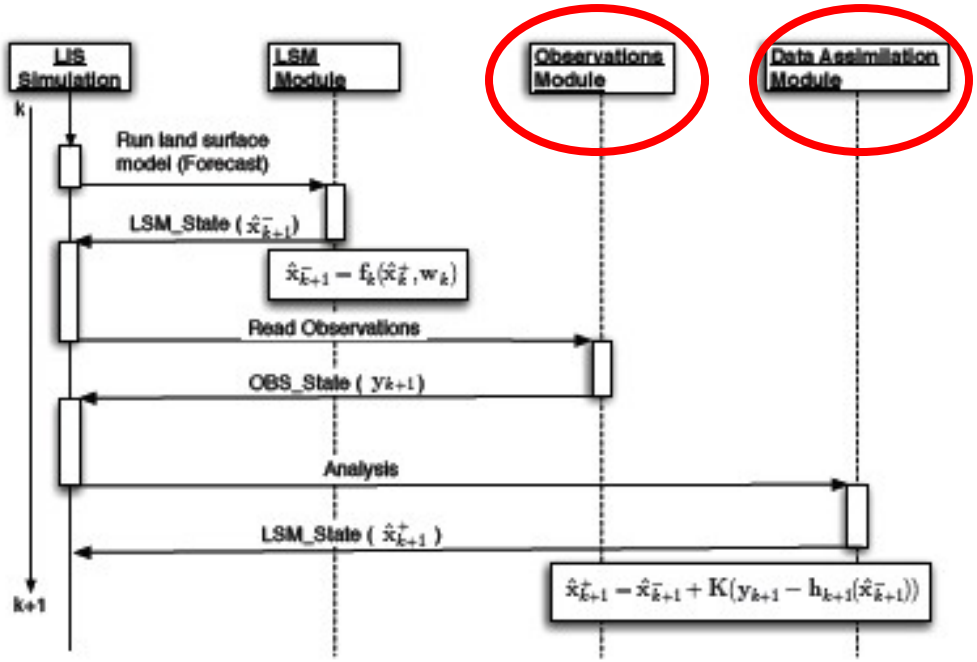
The Ensemble Kalman Filter

(*also supports extended Kalman Filter and Direct Insertion technologies)

LIS-DA Development

Generic LIS-DA framework already in place, including the NASA/GMAO EnKF module, and has been demonstrated for soil moisture and snow examples (Kumar et al., AWR 2008, in press):





For Tskin assimilation, need (at the minimum) a bias estimation module and a few plug-ins for Tskin observational data and Tskin EnKF update.

Ensemble Kalman Filter

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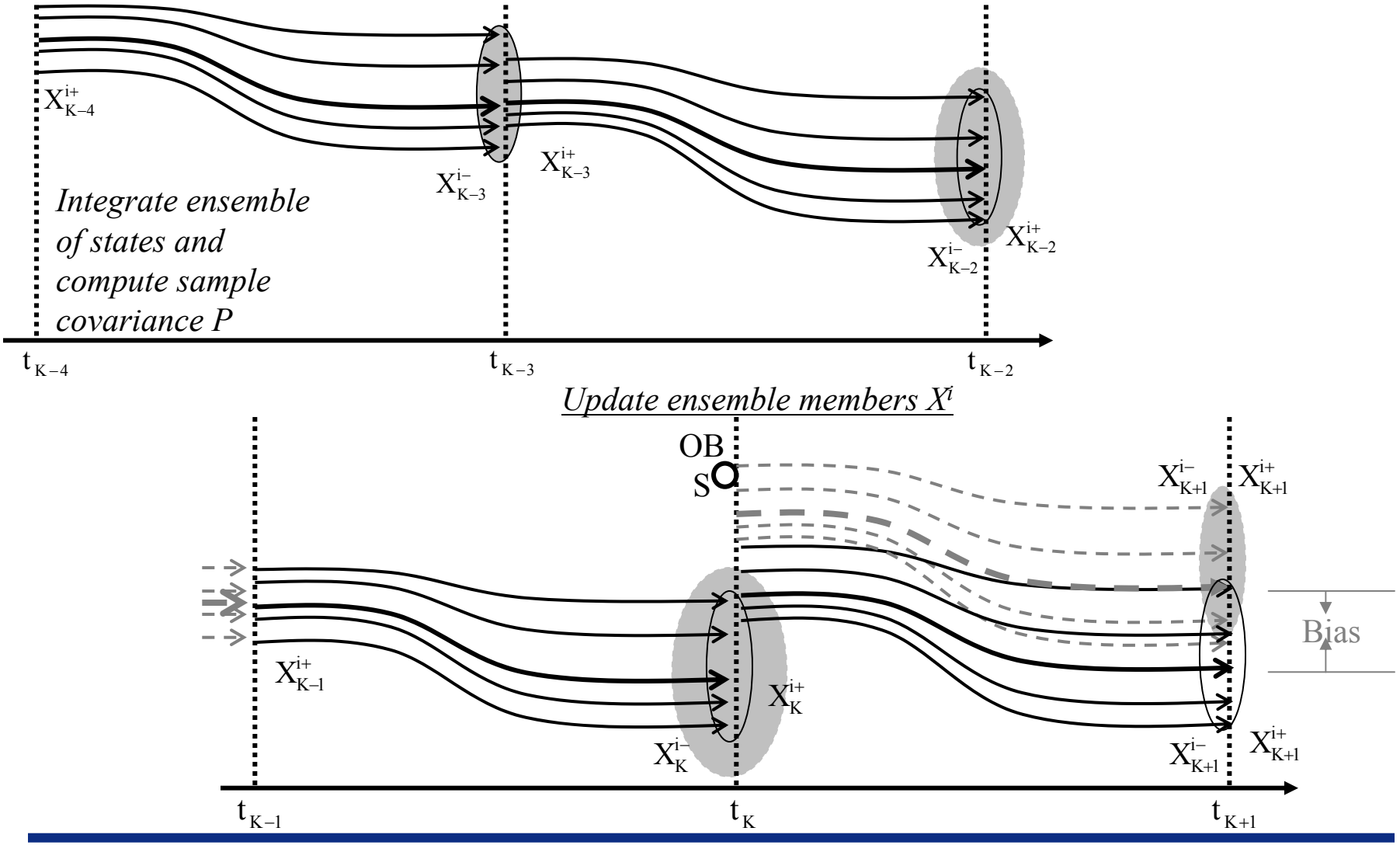

NASA LIS-DA Skin Temp Experiment

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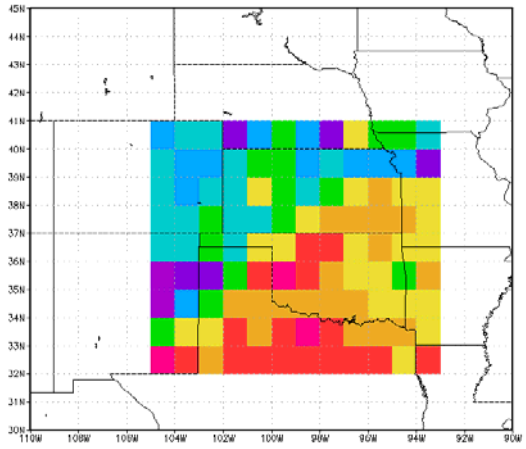
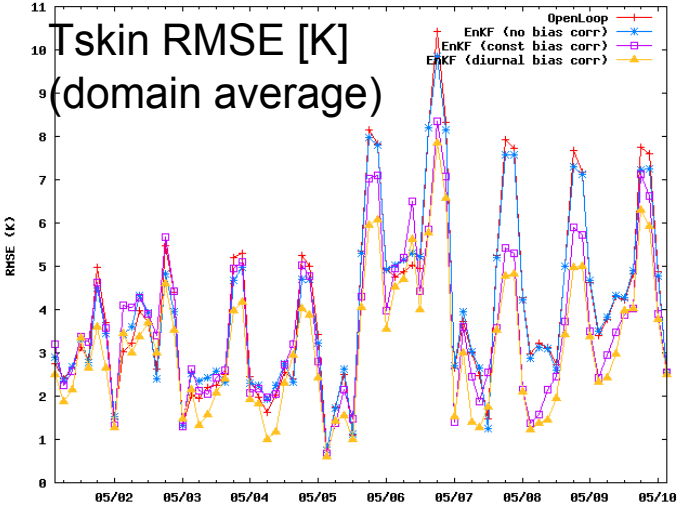
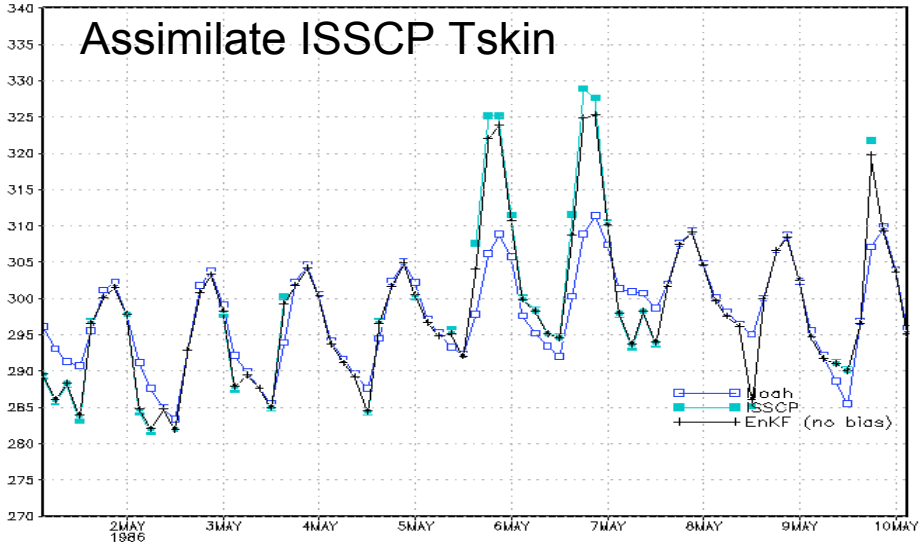


Twin experiment:
- Modeling domain around IHOP'02
- Catchment model for truth & synthetic obs.
- Noah LSM for open loop & assimilation
- GSWP-2 forcing (1986-1990), 1 deg grid





Demonstrated
ISCCP Tskin plug-in
for twin experiment setup

Plot shows time series for May 1986 (34N, 100W)

Current LIS R&D

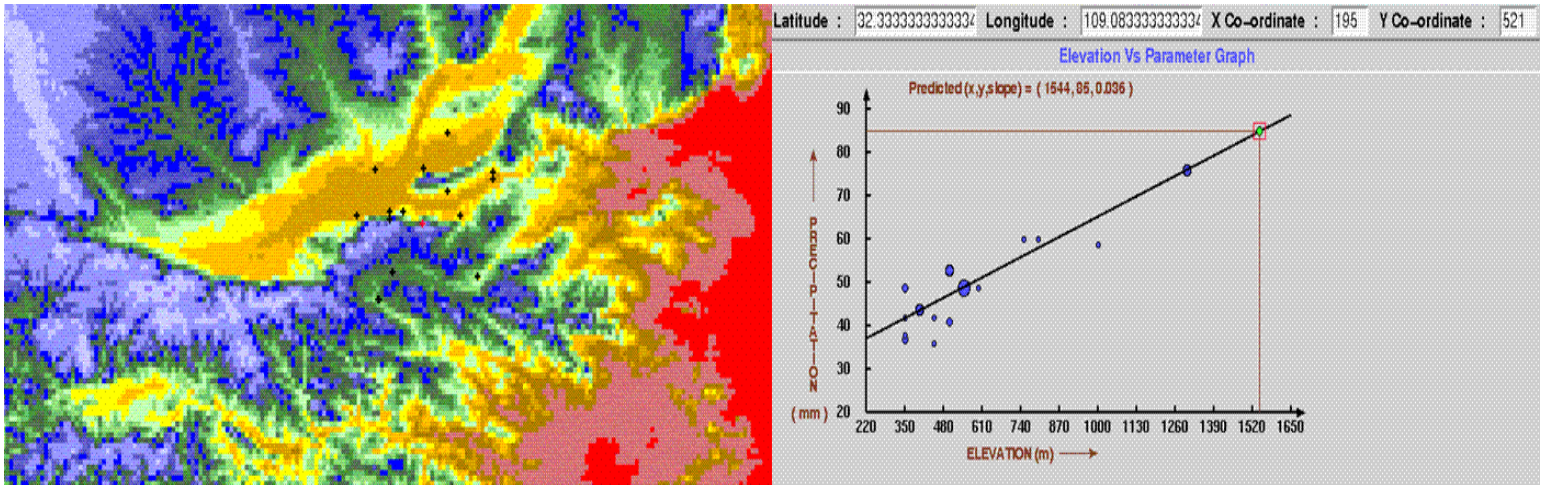
Precipitation Downscaling Project

PRISM climatology & analysis datasets

The Parameter-elevation Regressions on Independent Slopes Model (PRISM; Daly *et al.* 1994, *J. Appl. Meteor.*) is a knowledge-based system (KBS; Daly *et al.* 2002, *Clim. Res.*) used to generate estimates of climate parameters, e.g. T, T_d, P.

The PRISM KBS accounts for spatial variations due to:

- Physiography, including elevation, orientation, and profile
- Moisture regime, using an orographic trajectory model
- Coastal proximity, using a coastal wind infiltration model
- Topographic position, in the occurrence of inversions



PRISM climatology & analysis datasets

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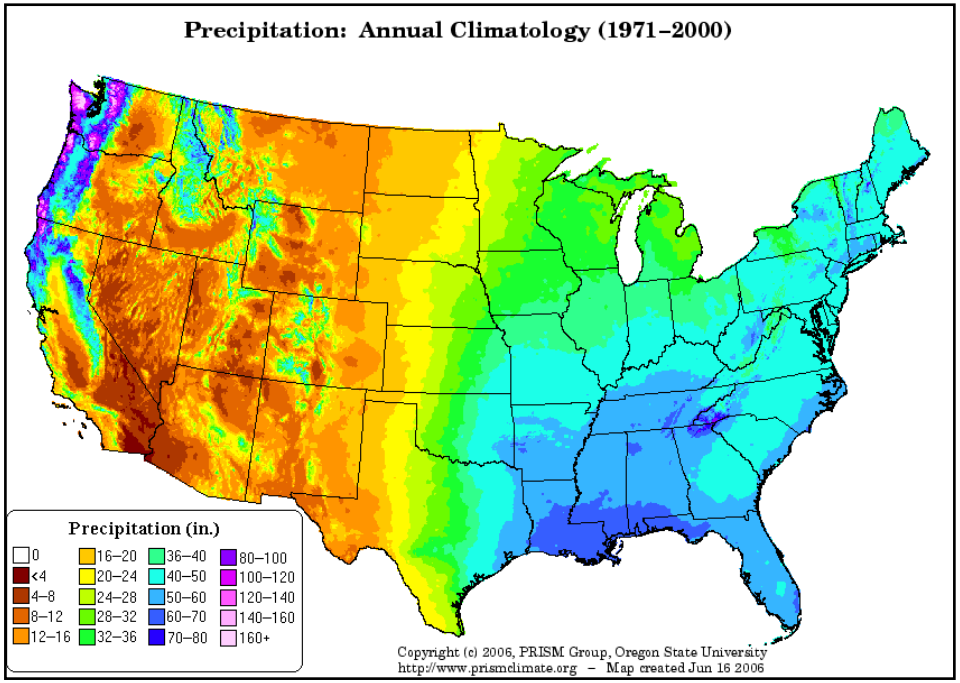
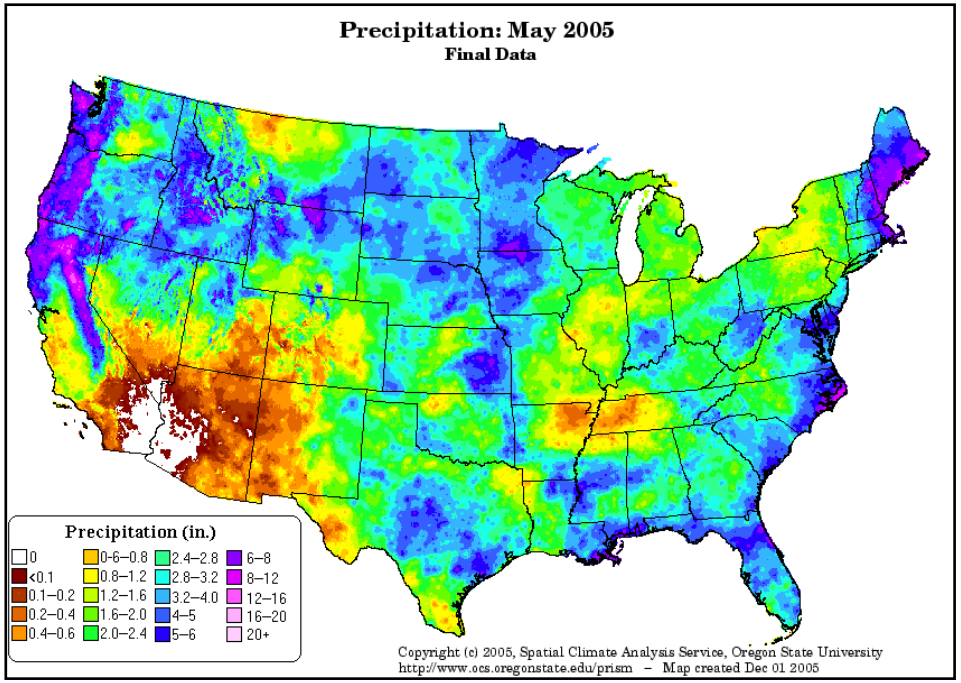
Monthly & Annual Climate



Monthly Analyses



Evaluating AGRMET: regional results (NW)

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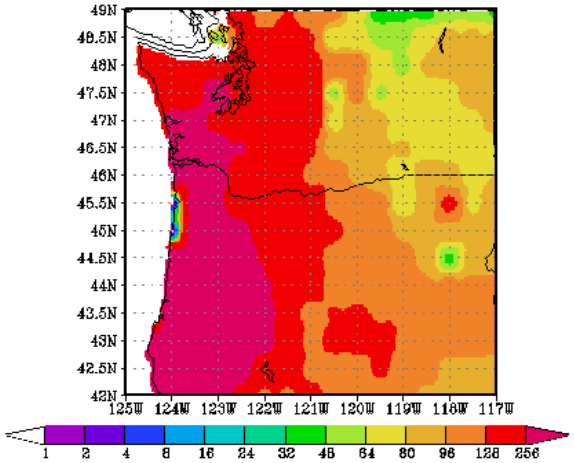
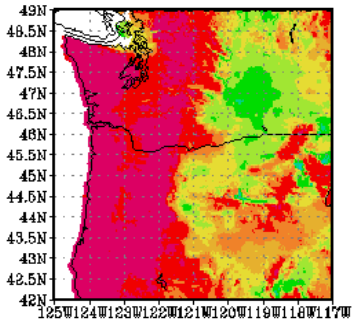
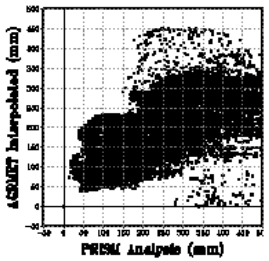
Dec 2005 AFWA AGRMET Interpolated Precip. (mm)



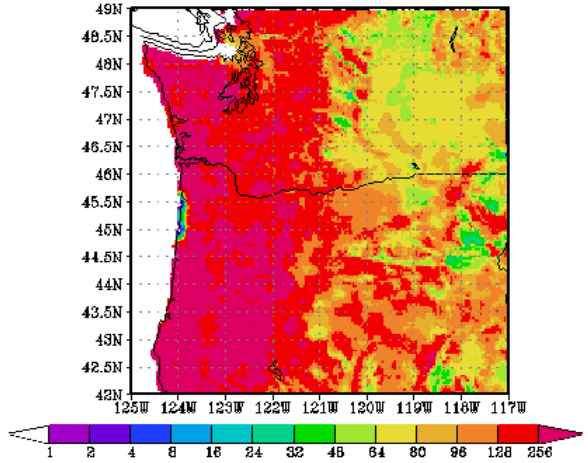
Dec 2005 PRISM Analyzed Precipitation (mm)



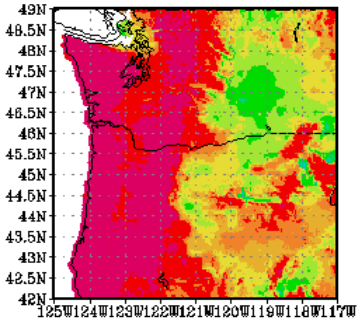


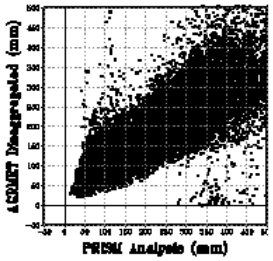
N = 29305	BS = 0.980515	N = 29305
Bias = −32.5658	POD = 0.980515	H = 28734
MAE = 68.8007	FAR = 0	M = 571
RMSE = 115.407	TS = 0.980515	F = 0
R^2 = 0.55508	ETS = 0	Z = 0

Dec 2005 AFWA AGRMET Disaggregated Precip. (mm)



Dec 2005 PRISM Analyzed Precipitation (mm)





N = 29305	BS = 0.980413	N = 29305
Bias = −20.2375	POD = 0.980413	H = 28731
MAE = 57.3734	FAR = 0	M = 574
RMSE = 121.949	TS = 0.980413	F = 0
R^2 = 0.468209	ETS = 0	Z = 0

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Precipitation Analysis
Enhancement Studies

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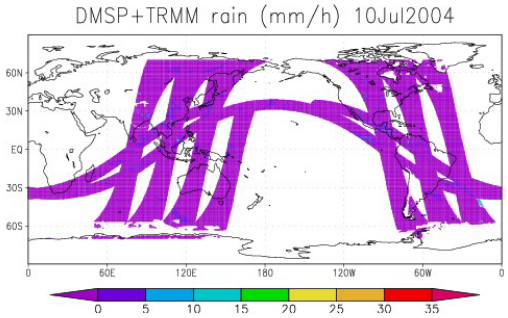
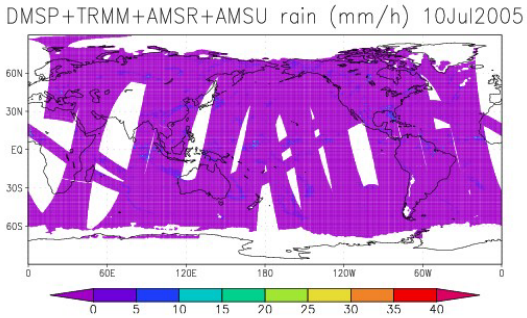
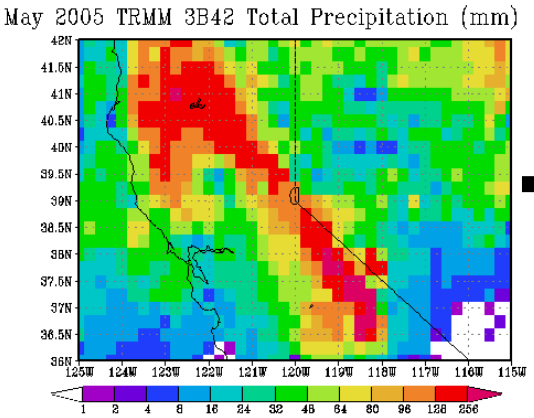
- **Increasing reliance upon space-based precipitation observations**

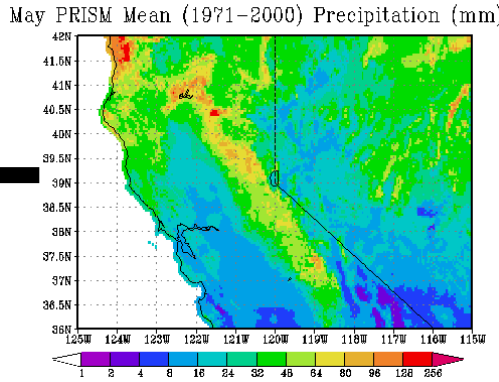




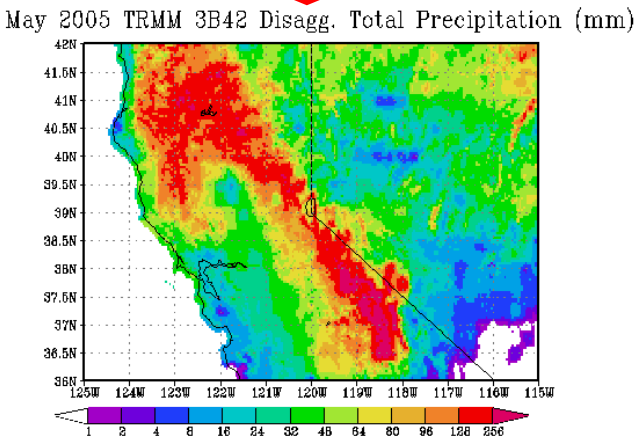
TRMM Estimate



High-Resolution Climatology



- **Use high resolution climatology (PRISM) to constrain satellite precipitation observations**



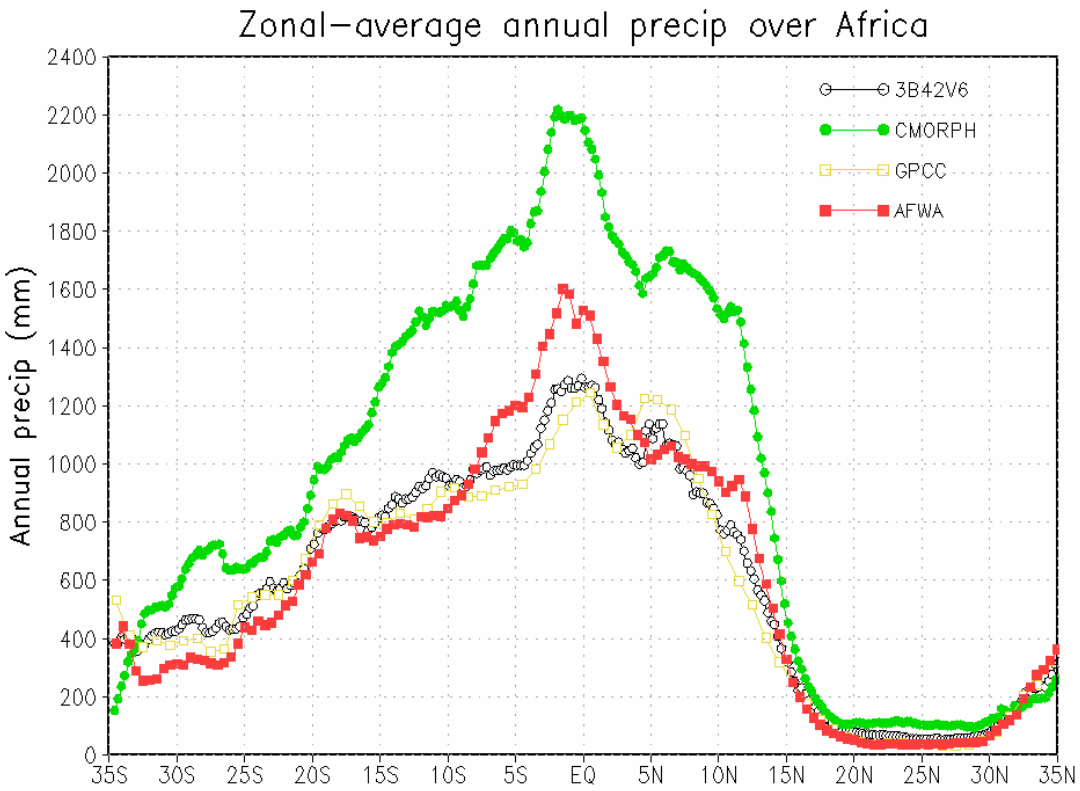
Downscaled precipitation analysis

[PRISM Group on the web– http://www.prism.oregonstate.edu](http://www.prism.oregonstate.edu)

AFWA Precipitation Analysis Study

Meridional distribution of annual rainfall across Africa

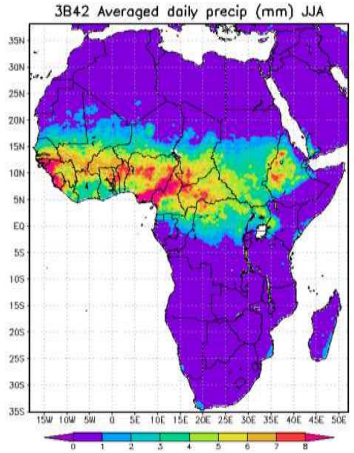
- **Comparison of annual rainfall climatology among the 4 products across Africa from South to North (left to right).**
- **Each dataset is a zonal average across the continent.**

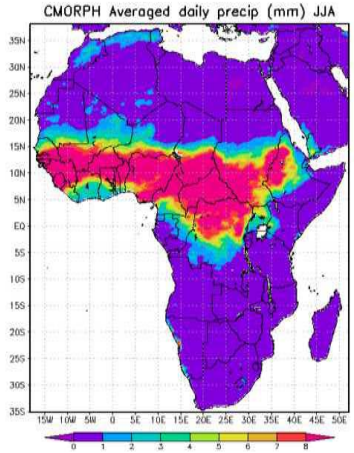


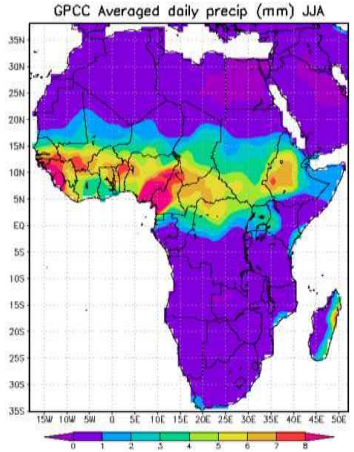
Africa Seasonal climatology (2003–2006)

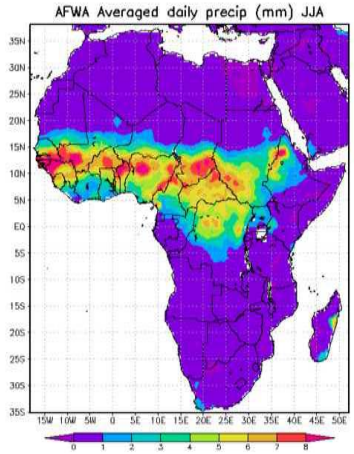
Summer and winter average daily rainfall from 3B42, CMORPH, GPCC and AFWA

Summer

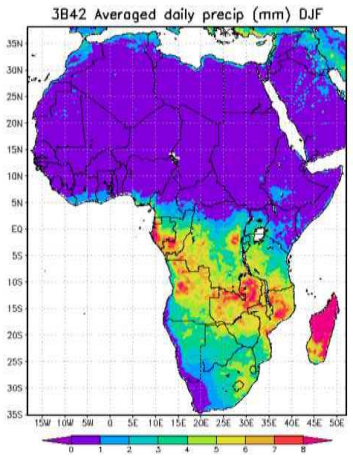


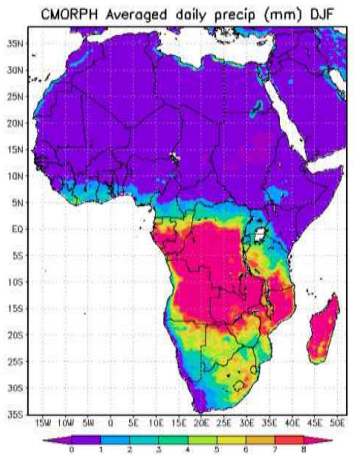


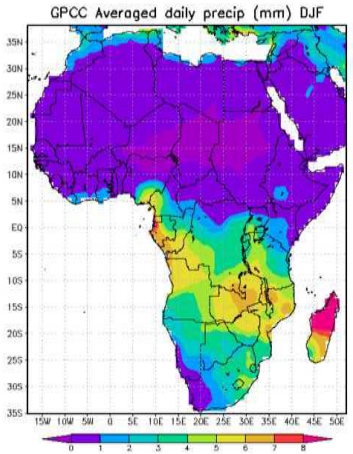


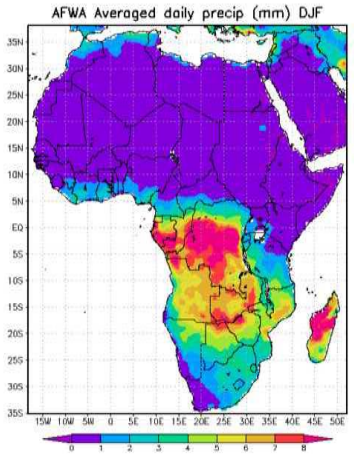


Winter









Current LIS R&D

LIS-WRF Coupling

LIS-WRF Coupling

AFWA, NASA & NCAR joint study

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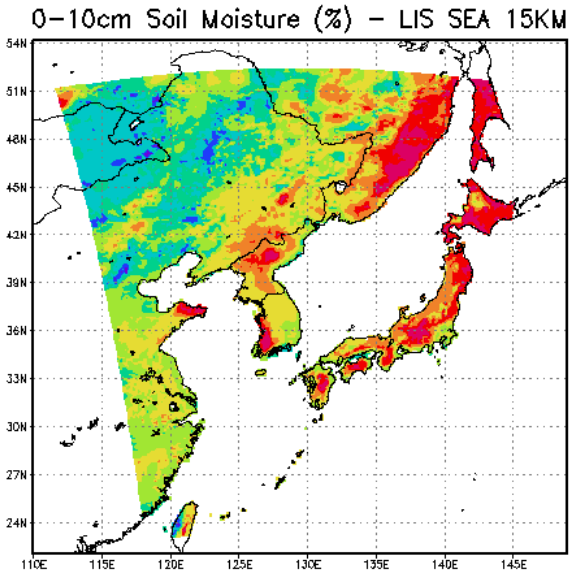
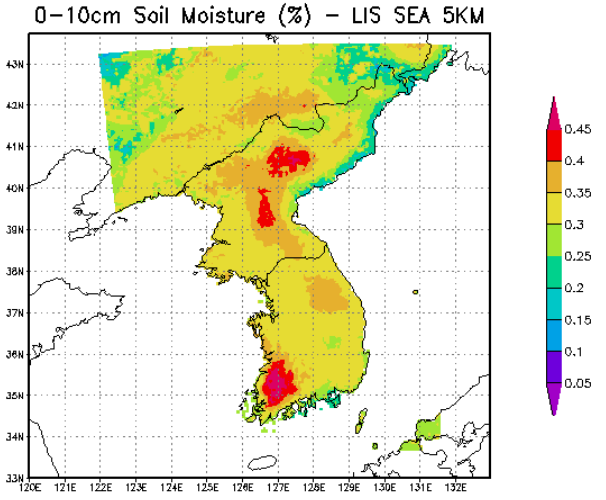
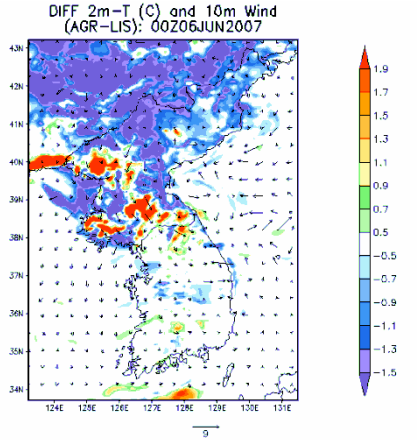


- Demonstrate and evaluate using LIS to initialize WRF (ARW) SE Asia domain
- 4 seasonal test case periods



STUDY RESULTS:

- LIS initialized runs were able to reduce WRF warm bias
- LIS affected 0-48 hour fcst variables of surface weather, boundary layer, cloud, and precipitation
- LIS soil and snow fields capture fine scale surface features, reflecting important role in high resolution NWP



Current LIS R&D

Snow Cover/Depth Analysis Improvements

Snow Cover/Depth Analysis

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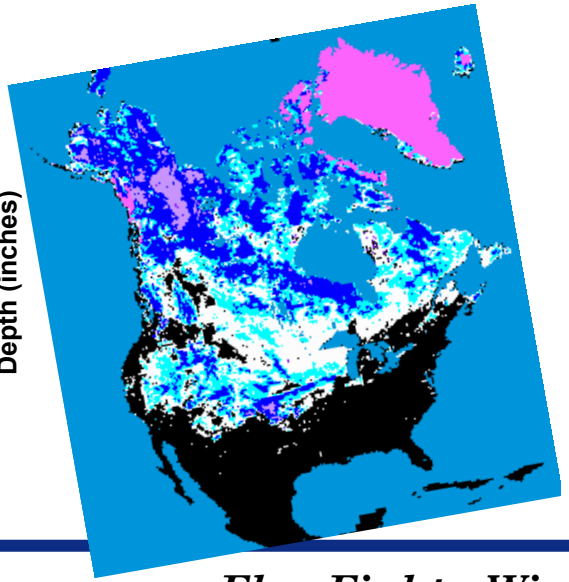
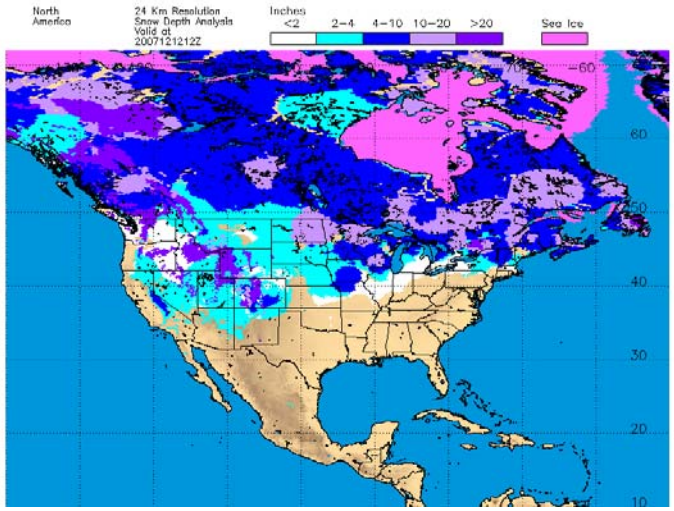
- AFWA-NASA Snow Algorithm (ANSA)
  - Improves upon the science contained within the AFWA Snow Depth Analysis (SNODEP) model
  - Merges microwave snow depth measurements (i.e. AMSR-E or SSMI/S) with visible NDSI snow cover (i.e. MODIS)
    - Current model uses primarily Synoptic Observations of Snow Depth, SSMI snow mask EDR, and climatology

AMSR-E SWE converted to Snow Depth (inches)



AFWA SNODEP model 20071212 12Z



AFWA-NASA Snow Algorithm (ANSA)

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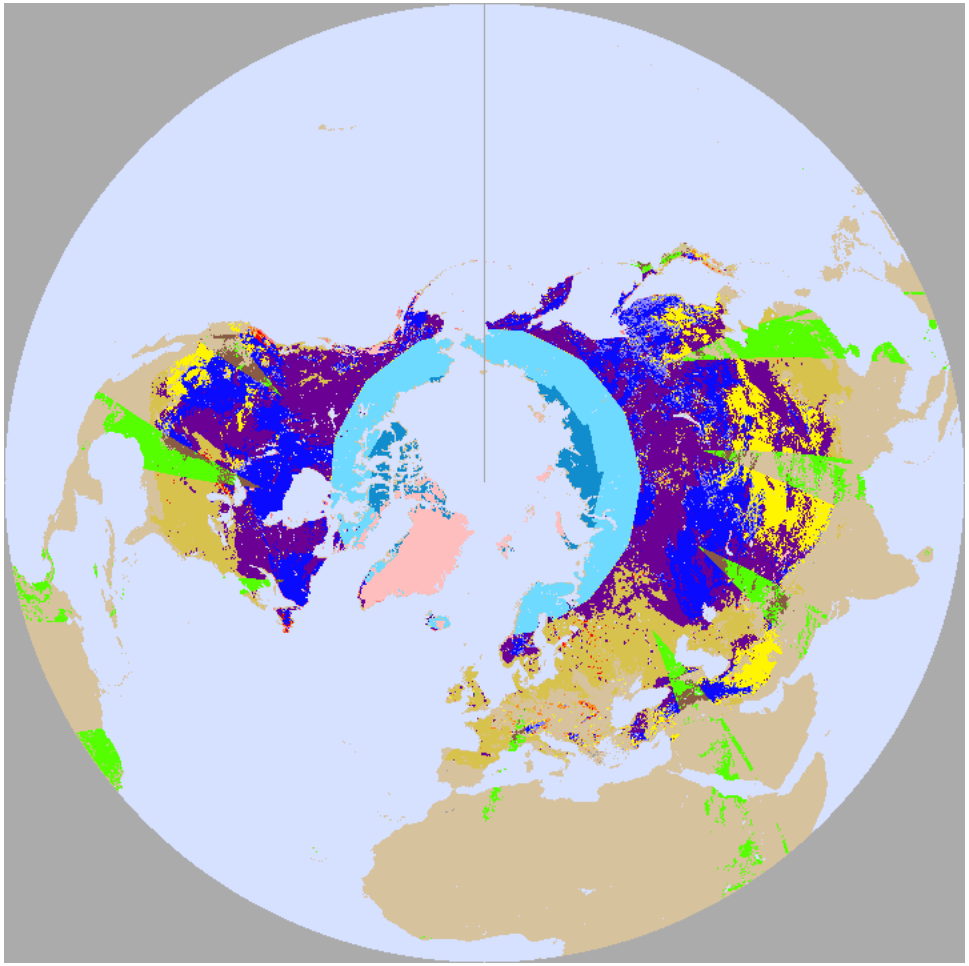
ANSA snow map 15 January 2007



Blended Snow Grid Values

- (575) MODIS snow 80-100% and SWE 2-480 mm
- (550) MODIS snow 21-79% and SWE 2-480 mm
- (450) MODIS snow 1-20% and SWE 2-480 mm
- (390) MODIS snow 80-100% and SWE 0 mm
- (370) MODIS snow 21-79% and SWE 0 mm
- (360) MODIS snow 1-20% and SWE 0 mm
- (375) MODIS snow 1- 100% and SWE water mask
- (355) MODIS snow 0% and SWE 2-480 mm
- (350) MODIS cloud and SWE 2-480 mm
- (330) MODIS cloud and SWE 0 mm
- (300) MODIS cloud in AMSR-E swath gap
- (345) MODIS snow1-100% in AMSR-E swath gap
- (305, 290) MODIS no data SWE 2-480 mm
- (295) MODIS in darkness and SWE 2-480mm
- (250) MODIS in darkness and SWE 0 mm
- (253) AMSR-E Permanent Snow/Ice
- (201) MODIS snow 1-100% and SWE land not processed
- (200) MODIS snow 1-100% and SWE no data
- (0) Land
- (1508) Ocean
- (1498) Fill

LIS Project Schedule

Additional capability development

- **Tentative development plans (dependant on AFWA funding)**
  - **FY09**
    - **Complete CRTM integration**
    - **Precipitation analysis improvements**
    - **Complete LIS-WRF full coupling**
  - **FY10**
    - **Examine Soil Moisture Assimilation**
  - **FY11**
    - **Vegetation conditions (vegetation health; leaf area index)**
  - **FY12**
    - **Assimilate snow pack properties through snow pack physics module**
  - **FY13/14**
    - **Distributed Watershed modeling (water routing)**

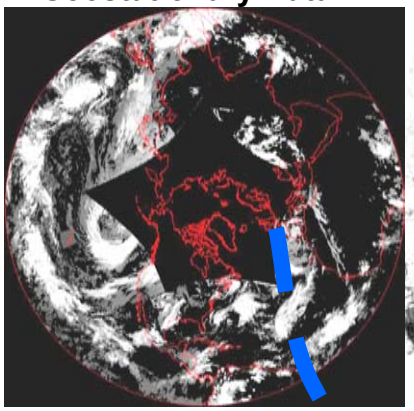
Cloud Characterization Improvements

Some of the cloud related material in this portion of the presentation originates from Atmospheric & Environmental Research, Inc (AER) personnel for work completed with AFWA or other DoD funded cloud analysis research and development project reviews.

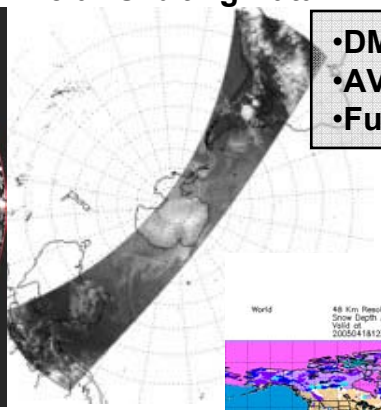
Global Cloud Analysis System

Cloud Depiction and Forecast System Version II

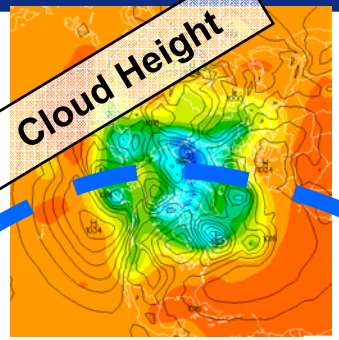
Geostationary Data



Polar Orbiting Data

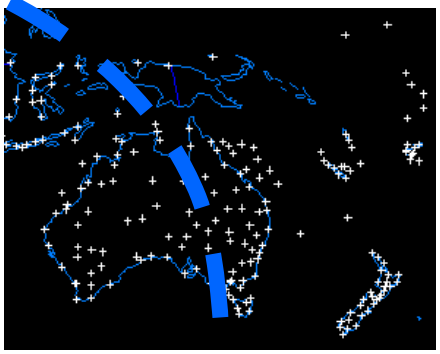


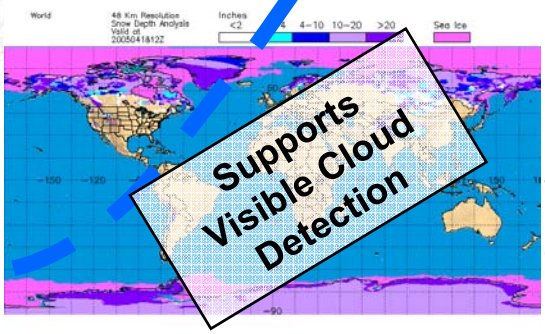
- DMSP
- AVHRR
- Future NPOESS



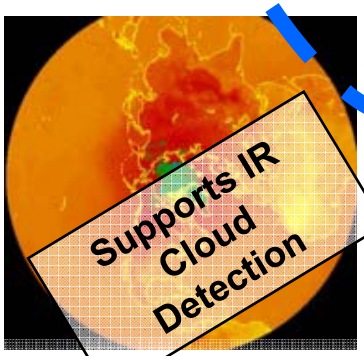
GFS
Upper Atmos. Temp
Near Surface Temp/RH/Wind

Surface Observations





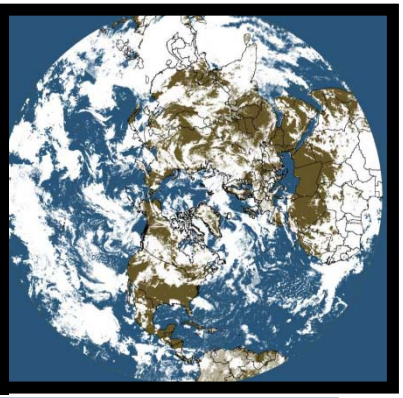
Snow Analysis
Resolution: 12 nmi
Obs: Surface, SSM/I
Freq: Daily, 12Z



Surface Temp Analysis
Resolution: 12 nmi
Obs: IR imagery, SSM/I Temp
Freq: 3 Hourly

World-Wide Merged Cloud Analysis (WWMCA)
Hourly, global, real-time, cloud analysis @12.5nm

Total Cloud **and** ***Layer Cloud*** **data supports National Intelligence Community, cloud forecast models, and global soil temperature and moisture analysis.**



Cloud Optical Properties

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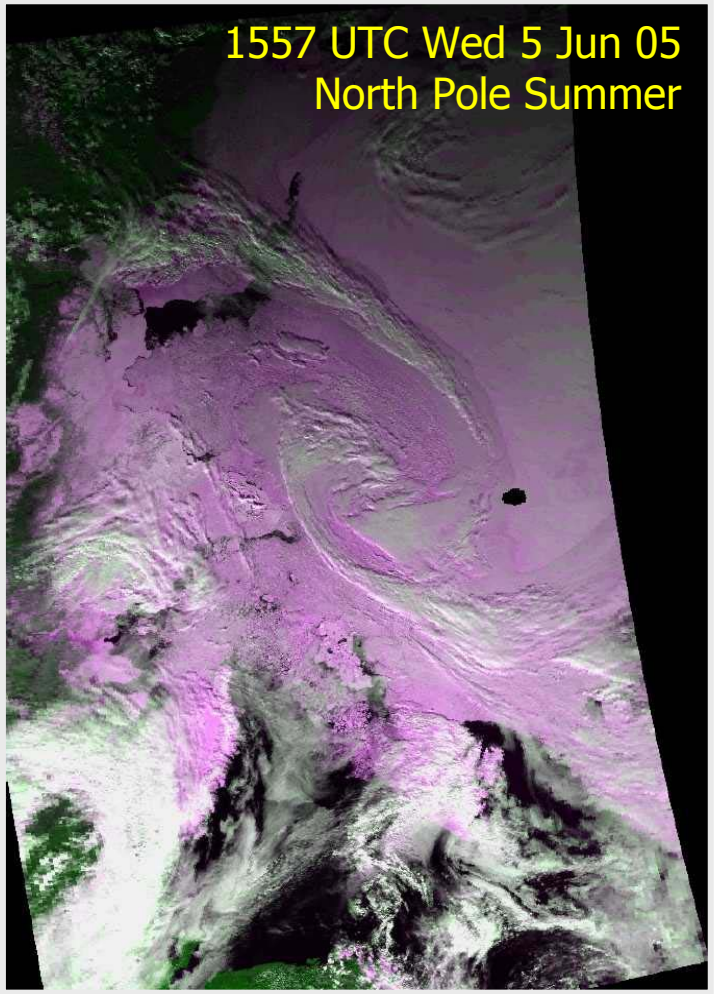
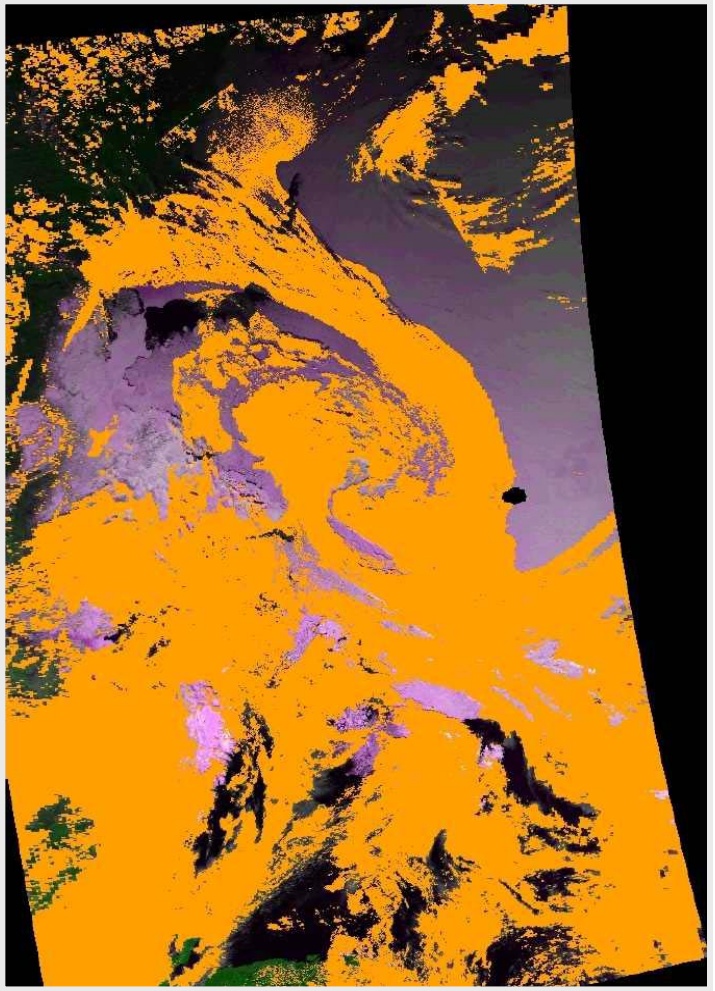


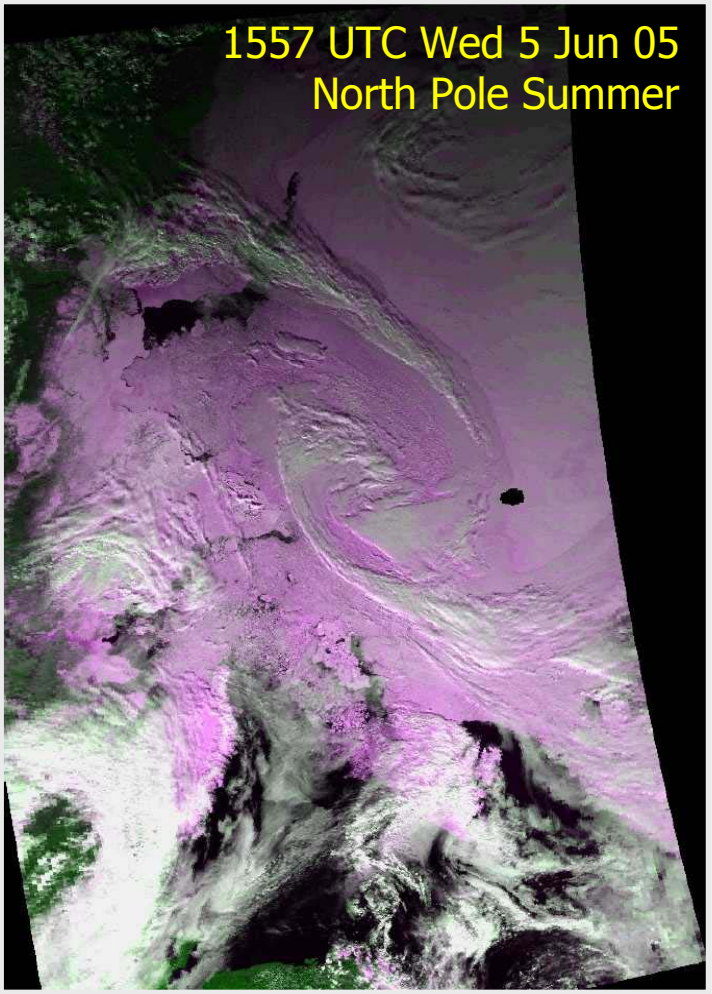
Visible - near-IR composite



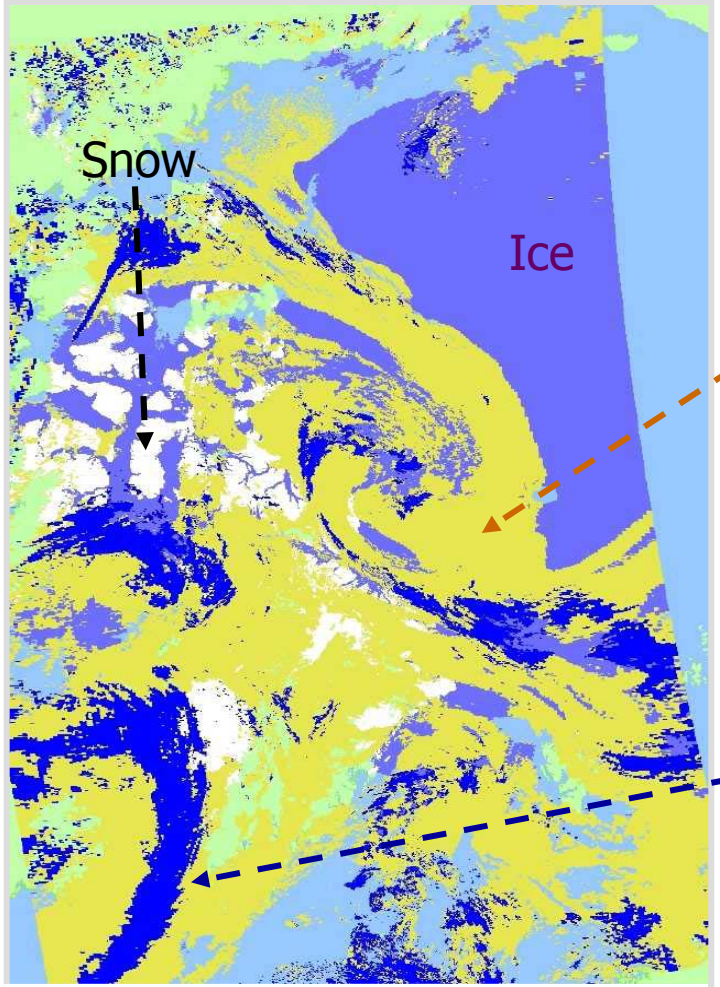
Cloud Mask

Cloud Optical Properties

U.S. AIR FORCE



Visible - near-IR composite



Cloud Phase, Snow, Ice Mask

Cloud Optical Properties
Demonstration

U.S. AIR FORCE

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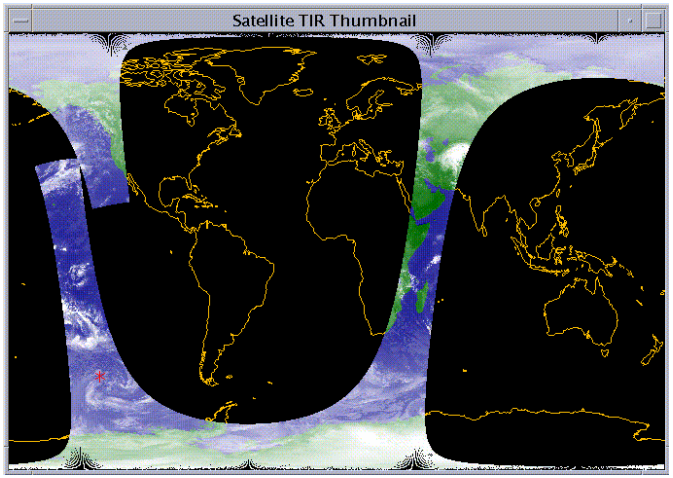
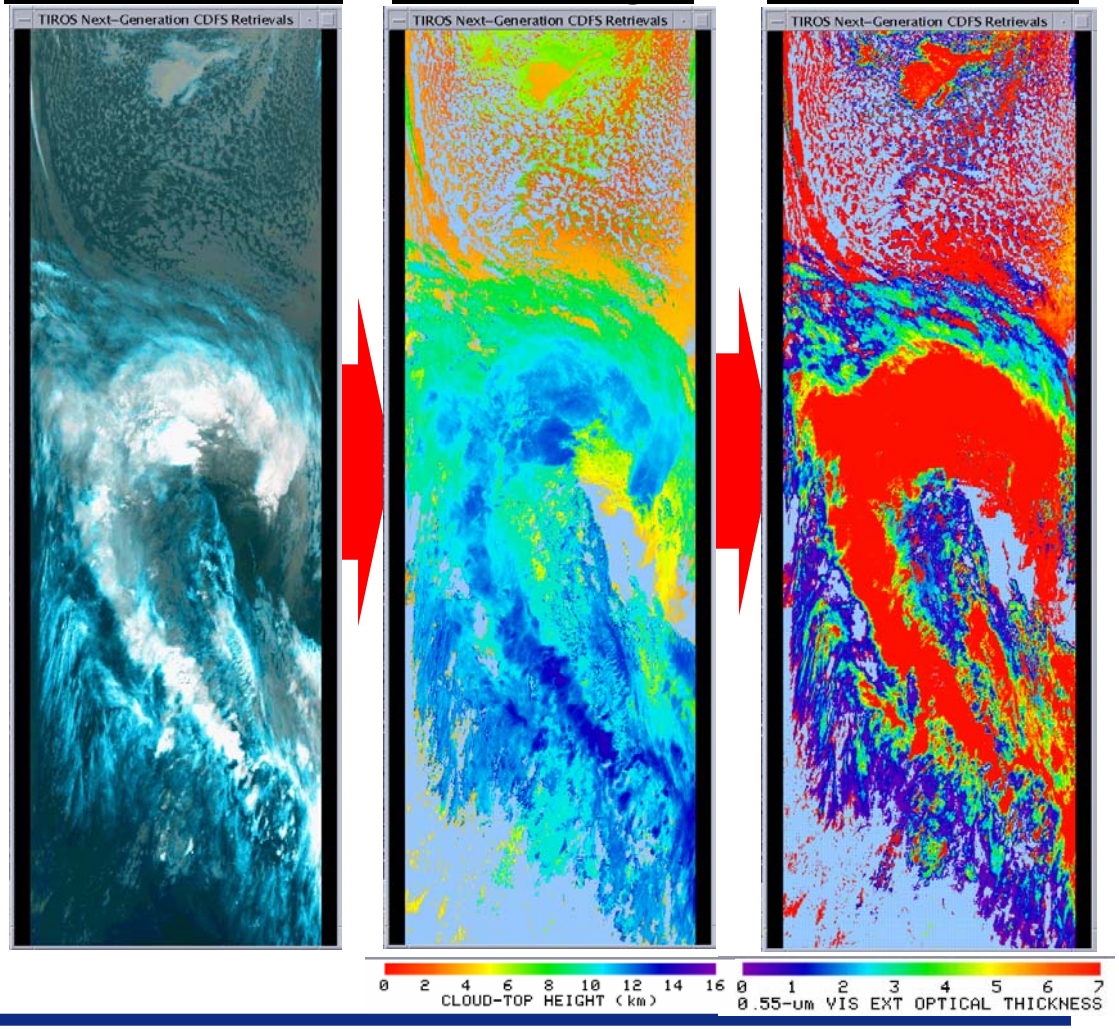


- Cloud Optical Depth (transmissivity) is directly measured within the new COP algorithms
- Able to identify transmissive cirrus clouds (ice)
- Currently limited to capturing one layer of cloud information

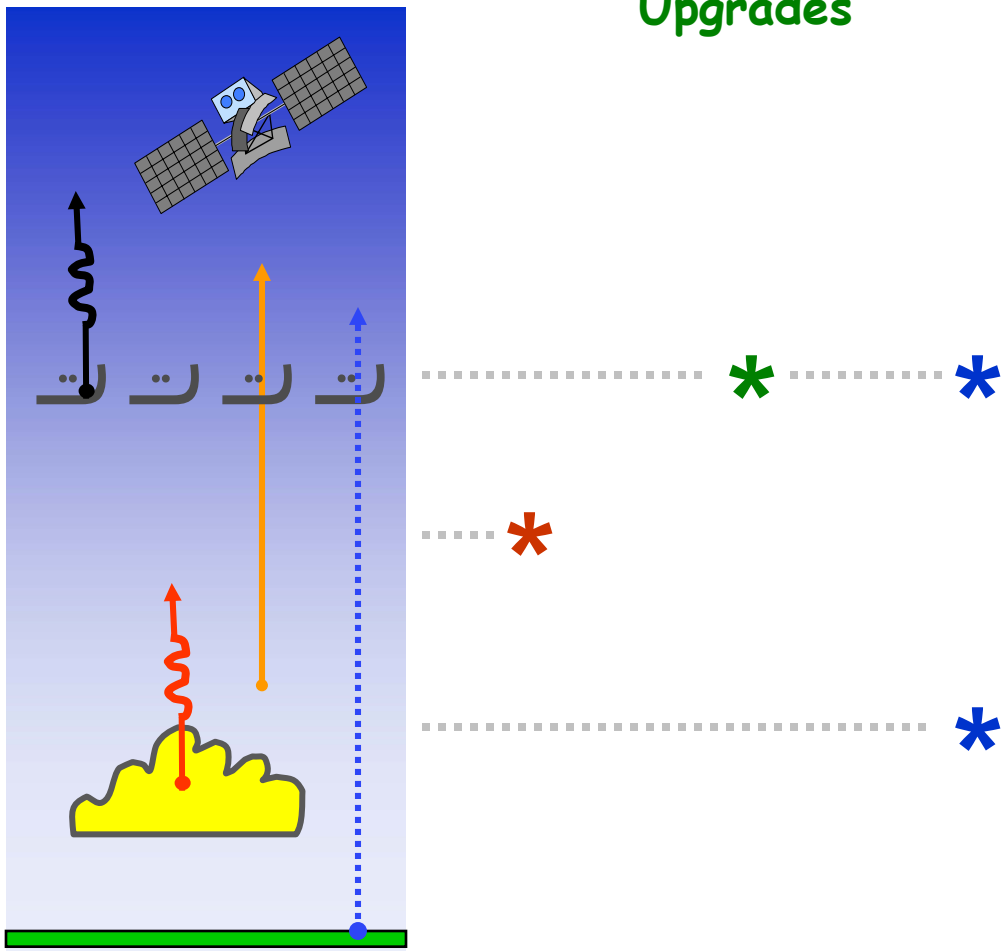
TIR Composite | **Cld Top Hght** | **Optical Depth**



CDFSII Cloud Optical Properties
Phase II (FY07) tasks

- Update Cloud Optical Properties algorithms to operate on NASA MODIS sensor and Meteosat SEVIRI sensor observations.
- New Prototype Capability:
  - Use a Radiative Transfer Model (RTM) combined with a 1D Variational (1D-VAR) data assimilation
    - 1st step towards detecting multi-layered clouds
    - Ensures consistency among all retrieved quantities
      - Artificially enforced in existing algorithms
    - Generalized approach for all sensor configurations
      - Provides working prototype for NPP
    - Exploits recent work by AER for JCSDA and NPOESS/IPO
- Optimization for transition to operations a major component of software development work
- Plan to use A-train to tune and validate final product

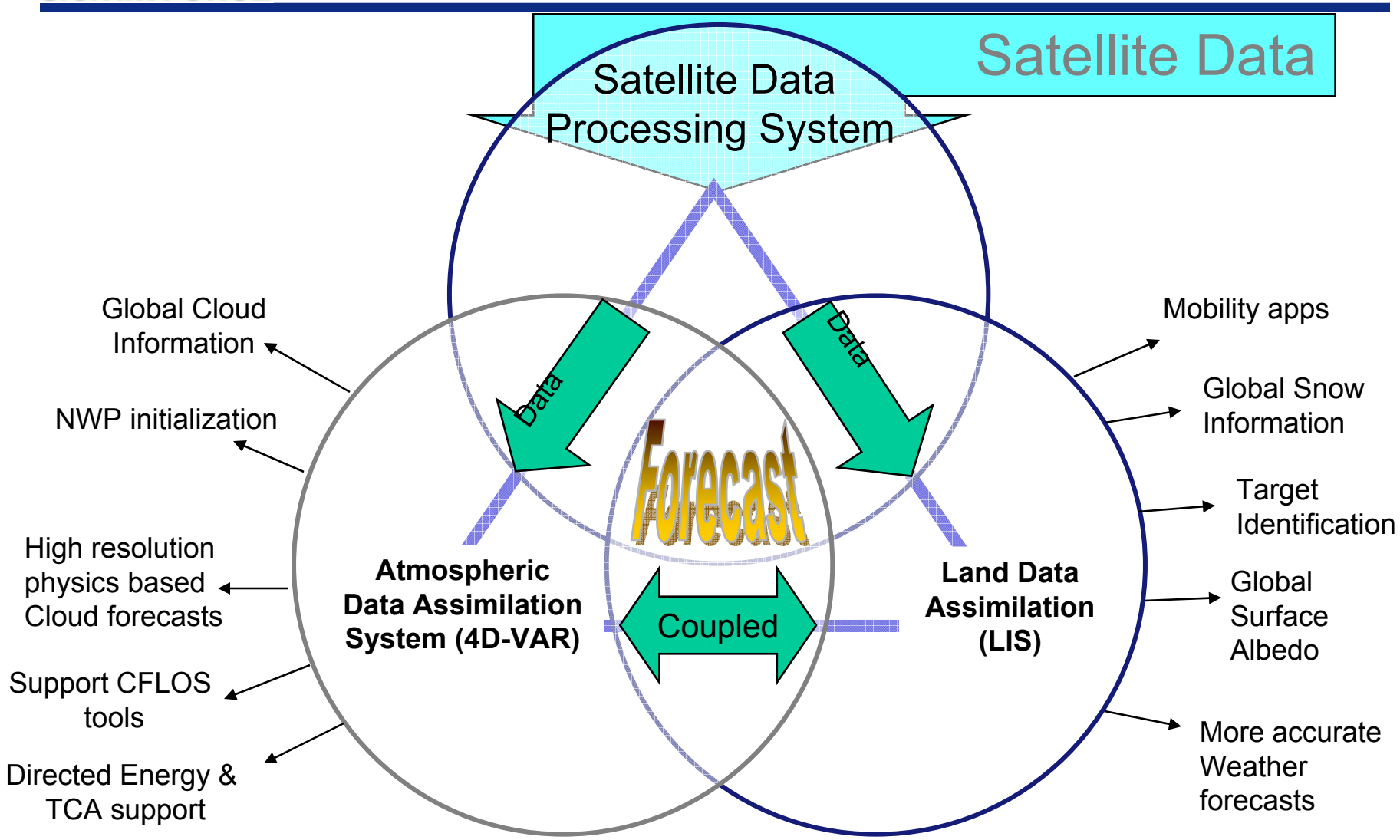
Retrieval Attributes



- CDFS reports one cloud-top retrieval per pixel
  - » no adjustment for transmissive effects
- Upgraded CDFS algorithms adjust for transmissive cirrus
  - » still one cloud layer
- 1D-VAR cloud mask identifies multilayer cloud conditions when the cirrus is transparent enough to "see" lower cloud
- Microwave

AFWA Coupled Analysis and Prediction System

Conceptual Design



Summary

- NASA-AFWA project resulted in a successful benchmarking test of LIS-AGRMET
  - AFWA driving toward Initial Operational Configuration by late CY 2008 or early CY 2009
- Once operational, AFWA will have a highly configurable land data assimilation system for land states analyses
  - Efficient common software infrastructure
  - Generates both global & regional surface states at multiple resolutions
  - Use multiple physics packages (LSM's)
  - R&D support to operations, more sufficient knowledge base
  - "NPOESS Ready"; ability to utilize high resolution satellite observations
  - More consistent NWP model initialization
- AFWA has been working to drastically improve surface characterization support for DoD and other US Gov't customers
- AFWA significantly investing in research to dramatically improve cloud characterization and cloud forecasting capabilities
  - Will improve surface characterization w/ improved energy flux estimates
  - Will support higher resolution requirements warfighter requirements

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Questions & Answers